DEVICE FOR MEASURING THE TEMPERATURE FIELDS OF ROTORS OF HIGH rpm GAS TURBINES

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Translation of "Apparatura dlya izmereniya temperaturnykh poley rotorov vysokooborotnykh turbin", Teplovyye Napryazheniya v Elementakh Konstruktsii, No. 14, 1974, pp. 139-142

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16. Abstract

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DEVICE FOR MEASURING THE TEMPERATURE FIELDS OF ROTORS OF HIGH rpm GAS TURBINES

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ABSTRACT. Current pickoffs are described which will measure reliably and precisely the temperature of turbine rotors operating at 30 to 40 thousand rpm, over long periods of turbine operation. Guidelines for the arrangement of the thermocouple junctions are presented.

Temperature measurements of all the rotating parts are a necessary element of the adjustment and testing of the lead models of new gas turbines. The reliable and effective coupling between the dozens of sensors (most often, thermocouples) mounted on the rotating parts and the fixed measuring devices is a very complex problem. The mercury and brush rings, which are used for analogous purposes in laboratory practice, as a rule, operate unsatisfactorily at high rpm (above 10,000 rpm). Their lifetime for the order of 20,000 revolutions does not exceed 30 - 40 minutes**.

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*Numbers in the margin indicate pagination in the original foreign text.

**Zedginidze, G. P. Izmereniye temperatury vrashchayushchikhcya detaley mashin (Temperature Measurement of Rotating Machine Parts). Moscow, Mashgiz, 1962.

Slip ring devices, suitable for extended (dozens of hours) temperature measurements of turbine parts rotating at 30 - 40,000 rpm, have been produced at the Institute of Technical Thermal Physics (ITTF) AN UkrSSR. Laboratory and stand tests carried out at ITTF AN IkrSSR have shown that to solve these problems, it is advisable to use slip rings operating on the sliding contact principle. With the use of mercury slip rings, it is difficult to dissipate the heat being developed directly at the contact zone. Because of this, mercury slip rings have a complex design and a small (the order of several minutes) operating time at high rpm.

In the slip rings with sliding contacts described by G. P. Zedginidze (cf. footnote**, p. 1), there appear significant pulsating contact thermal emf and variable intermediate resistances arising in the ring-brush pair at high rpm. These deficiencies, as investigations carried out at ITTF AN UkrSSR have shown, can be significantly reduced or even eliminated by the proper selection of materials for the contact pair and the optimization of its operating mode.

The selection of a contact pair with good characteristics is a very complex problem. Such a pair must have high electrical conductivity, good mechanical stability and wearability, have minimum and stable contact resistance and contact thermal emf. A material satisfying all requirements could not be selected by the laboratory tests of 15 contact pairs. Thus, for the design of slip rings, a compromise solution had to be taken: to use a contact pair satisfying only the basic requirements. The main attention was given to the selection of a pair which, at significant sliding rates (up to 40 - 50 m/sec), would have the minimum and stable contact thermal emf.

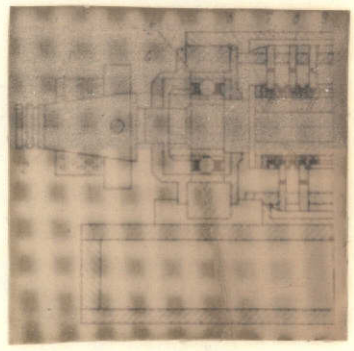
It was assumed that by using compensating measuring circuits or measuring circuits with high internal resistance, one could completely avoid the effect of instability of intermediate resistances (with 1/10 ohm). Of the 15 most promising pairs (copper, brass, bronze, and silver rings with various brushes), the best pair was found to be a brush of type MG and ring of M-1 copper. This pair

had the smallest values of contact thermal emf and its time variation of all the investigated pairs; the variations of the intermediate resistance did not exceed 0.03 ohm. The contact pair of MG brush and copper ring has good mechanical stability, wearability, and quite satisfactory durability. At sliding rates less than 10 m/sec, the contact pair of brush of the type MG and ring of L62 /141
brass has better characteristics.

The thermal emf of the contact depends significantly on the specific pressure of the brush on the ring; thus, to decrease the noise introduced by the slip ring into the measuring line, it is necessary to ensure equal (or almost equal) pressure of the brushes for all ring pairs.

Several types of brush slip rings with pneumatic pressing of the brushes, which satisfy the enumerated requirements, have been produced at ITTF AN UkrSSR.

The slip ring (cf. Figure) consists of a shaft 4 mounted on a rigid base 1 in bearings 5. The contact rings 6 are set up on the shaft. Copper leads from them pass through radial holes in the shaft and the internal cavity and are soldered to contacts of the coupler 3. The coupler lead 2 serves to connect the slip ring with the help of an intermediate object (durite, slotted coupler, coil spring, etc.) to the test object. The thermal emf is taken from the contact rings by the brushes 9 mounted on sheet springs. Copper leads from the brushes go to terminal joints mounted on the side of the slip ring. The brushes are pressed to the rings by steel plungers 8, which are insulated from the brushes by compressed air supplied from the distribution chamber 7. This provides the same force pressing the brushes to the rings.



Type of slip ring	No. of ring pairs	Maximum rpm	Contact ring outside diameter (mm)	Measurement error (at max. rpm) (mV)	Center height (mm)	Dimensions (mm)
SK-16	12	36,000	19	± 0.1	55	235 × 120
SK-17A	21	25,000	24	± 0.1	55	335 × 120
SK-19	32	15,000	26	± 0.1	55	400 × 140
SK-20	60	5,000	28	± 0.05	70	625 × 155

The pneumatic press permits not only an easy establishment of the necessary force pressing the brushes to the rings providing reliable contact between them, but also makes it possible to put the slip ring into operation only at the time the measurements are carried out. This sharply reduces the wear of the contact pair, and significantly increases the lifetime of the slip ring. Supply of air or inert gas is provided for cooling the contact pair and removing wear products.

To determine the temperature of the cold junctions of the thermocouples, a thermistor — whose ends are soldered to the coupler terminals and are brought out through a ring and brush to the terminal joint — is mounted in the coupler of the slip ring. The resistance of the thermistor is measured by a bridge circuit. Its parameters are selected to that the errors in measurement due to heating of the thermistor by the measuring current are reduced to a minimum.

In some of the slip rings, the bridge power supply and its two constant resistances are mounted in the base, and the variable decade resistances in the null device are connected to the terminal joint. The basic characteristics of the slip rings are presented in the table.

All the slip rings can be fabricated as feed-through type; this permits installing them sequentially and increasing the number of measuring points.

The slip rings of the type SK-16 operate reliably at the maximum rpm for no less than 25 hours with pressed brushes. For the other slip rings, as well as for the slip rings of type SK-16 but for a smaller number of rotations (70 - 75% of the maximum), the operating life with pressed brushes is more than 150 hours.

These slip rings are being fabricated at ITTF AN UkrSSR in small orders, and have been successfully used at a number of enterprises and scientific research organizations.

Chromel-alumel and chromel-kopel thermocouples with thermoelectrode diameter of 0.2 - 0.5 mm were used as temperature sensors in the experiments on gas turbines. /142

Silicone fiber is used to insulate the electrodes of the chromel-alumel thermocouples; glass fibers are used for the chromel-kopel. After winding, the thermoelectrodes are soaked with the heat-resistant varnish FEPS or FG-9. The thermocouples are fitted into specially milled shaped grooves. The tips are welded by the contact method, a band of foil of heat-resistant steel 0.1 mm thick is applied to them and welded to the disk which protects the hot junction of the thermocouple from being torn off under the effect of centrifugal forces. Then the thermocouples are fitted into the grooves and covered level with foil of heat-resistant steel 0.1 mm thick, which is welded to the disk by the contact condenser method.

To measure the gas flow temperature, the hot junction of the thermocouple is mounted on a special mount, 7 - 10 mm high, of heat-resistant foil about 0.1 mm thick welded to the side of the disk. Such a mounting prevents shorting of the thermocouple tips to the frame, and significantly decreases the heat exchange between the tip and the disk frame along the thermoelectrodes.

To mount thermocouples in the interior, a band of copper foil is used, which has a fork-shaped slit at the end. The thermocouple tip, together with the fork, are introduced into a previously drilled hole and tightly pressed to its bottom. The current from the

condenser machine is supplied through the fork. The thermocouple tip is welded to the metal of the disk, and the foil band is removed. Then the hole is covered by a foil of heat-resistant steel and welded to the disk by a condenser welding.

A small series of portable condenser welding machines of the type PKTM-3 for welding thermocouples and foil to ferrous metals has been developed and produced at ITTF AN UkrSSR. It is Supplied from the electrical system; its weight does not exceed 12 kg. The machine provides reliable welding of any steel of thickness 0.05 - 0.7 mm, and also welding of leads and bands to large parts.